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## Structural, Optical and Radiation Shielding Properties of BaO-B<sub>2</sub>O<sub>3</sub>-Rice Husk Ash Glasses

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### Abstract

This paper is reports on the structural optical and radiation shielding properties of development barium-borate-rice husk ash glasses (RHA) system. The glasses containing BaO in  $x\text{BaO}:(80-x)\text{B}_2\text{O}_3:20\text{RHA}$  where  $x = 45, 50, 55, 60, 65$  and  $70$  wt.% have been prepared by melt quenching technique. The structural properties of these glasses are shown from density data and molar volume. The optical property was investigated using UV-Visible spectra. The mass attenuation coefficients of the developed glass system have been determined using narrow beam transmission geometry at 662 keV. The results are corresponding with theoretical calculation from WinXCom software.

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**Keywords:** borosilicate glasses; rice husk ash; mass attenuation coefficient; gamma-ray shielding

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### 1. Introduction

Borosilicate glass is a one type of important glass with the main glass-forming constituents' silica and boron oxide. These glasses have attracted extensive research, due to their wide applications in various fields such as optoelectronics, thermo chemical, solar energy technology and nuclear with excellent transparent, low thermal expansion coefficient, high soften temperature, high refractive index with low dispersion and a high resistance to chemical attack properties [1]. These properties can further be adjusted through selecting appropriate glass constituent. Intermediate oxides are intentionally introduced in the

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selected glass composition which can act as a glass former or glass modifier depending upon their amount in the selected glass composition. Barium is a one of alkaline earth metals that have a dual property are network former and network modifier and a good candidate in nuclear waste [2-4] and radiation shielding property [5] because it's has a strong absorption of X-rays, gamma-rays, high density and the most important, barium is non-toxicity compared with lead.

In Thailand, a rice husk is one of the major agricultural wastes. The large proportion of it has been recycled as a raw material for Portland cement and another application e.g. refractory, insulator, waterproofing chemicals etc [6]. Nevertheless, the usage in these applications has low values in economics. Therefore, it is necessary to search for a new option for the usage of the rice husk ash. When the rice husk ash was burnt, it has a high silica content and low transition oxide contamination. Therefore, the burnt rice husk ash can be substituted for a silica source in the process of fabricating a borosilicate glass.

So that, the aim of this work is to fabrication of barium borosilicate glasses using rice husk ash as a silica source and studied structural, optical and radiation shielding properties of these glasses.

## 2. Experimental

### Glasses Preparation

Six rectangular shaped glass samples of composition  $x\text{BaO}:(80-x)\text{B}_2\text{O}_3:20\text{RHA}$  (where  $x = 45, 50, 55, 60, 65$  and  $70$  wt.%) have been prepared by using melt quenching technique. The oxides of barium and boron used in this work were of analytical reagent grade, and the oxide of silica was of rice husk ash procured from the Nakorn Pathom Province, Thailand. The rice husks were placed in alumina crucibles and then burnt at 400, 600, 800, 1,000 and 1,100 °C for 5 hour in a muffle furnace. The chemical composition of rice husk ash whose component is not known was analyzed with an energy dispersive x-ray fluorescence (EDXRF) instrument of type Panalytical, Minipal 4 spectrometer (PW 4030/45B) with an Rh X-ray tube operate. For the preparation of a glass sample an appropriate amounts of BaO,  $\text{B}_2\text{O}_3$  and rice husk ash (at highest silica content) were weighed using an electronic balance having accuracy of order of 0.0001 g.

Table 1. Chemical composition by weight of rice husk ash (burnt at 1,100 °C)

Compound	wt. %					
	$\text{SiO}_2$	$\text{P}_2\text{O}_5$	$\text{K}_2\text{O}$	$\text{CaO}$	$\text{MnO}$	$\text{Fe}_2\text{O}_3$
Rice husk ash	87.20	1.64	6.23	3.12	0.82	0.97

The chemical were mixed and contained in the crucible to place in an electric furnace at 1,200 °C for an hour. The melt was poured into a preheated stainless steel mold. The glass samples was then annealed in a separate annealing furnace for 3 hours and then slowly cooled to room temperature. The thickness of prepared samples was measured by vernier calliper, which can measure down to 0.05 mm. The density of each sample was measured by Archimedes' principle using distill water as the immersion fluid from applying the relation:

$$\rho = (W_a / W_a - W_b) \rho_{\text{distill water}} \quad (1)$$

where  $W_a$  and  $W_b$  are the weight of samples in air and the immersion fluid, respectively. The density of distilled water is  $1.00 \text{ g/cm}^3$ . The corresponding molar volume ( $V_M$ ) was calculated using the relation,  $V_M = M_T/\rho$ , where  $M_T$  is the total molecular weight of the multi-component glass system. The experiment was repeated three times for density and thickness measurement. The chemical composition (wt.%), density and molar volume of prepared glass samples are enlisted in Table 2. The optical absorption spectra were recorded at room temperature using a UV – visible spectrophotometer (Cary-50), working in  $300 - 1,100 \text{ nm}$  at room temperature.

For radiation shielding properties, a narrow beam  $\gamma$ -ray transmission geometry was used for the attenuation measurements of prepared barium-borate-rice husk ash glass samples. The diagram of the geometry is shown in Fig. 1. The source was enclosed in a lead container with one face aperture, 3 mm. in diameter. Samples were positioned on a specimen holder at 400 mm. from the source. The distance between source and detector is 550 mm. A  $2'' \times 2''$  NaI (Tl) crystal detector with the energy resolution 8 % at 662 keV and Multi-Channel Analyzer (MCA) plug-in-card were used with associated electronics to record the pulse-height spectra to a  $^{137}\text{Cs}$  radioactive source. The radioactive sources were procured from Office of Atom for Peace (OAP), Bangkok, Thailand. The intensities of photon were measured without and with placing the sample between source and the detector. The intensities of incident and transmitted photon,  $I_0$  and  $I$ , respectively, were measured for a fixed preset time by selecting a narrow symmetrical region with respect to the centroid of the photo peak. The net area under each peak gives the intensity of gamma-rays. The counting time for each measurement was chosen so that  $10^5$  counts were recorded under each peak given a statistical accuracy better than 0.3 %. The statistical error in this experiment was calculated from the relative error, ratio of standard deviation to mean values in three stages (i) ray-sum measurement, (ii) density measurement and (iii) thickness measurement. Finally, the total error has been determined from combining the errors for three stages in quadrature [7].

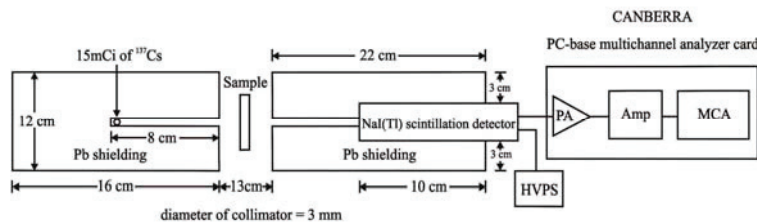


Fig. 1. Experimental setup of narrow beam transmission method

### 3. Results and discussions

#### 3.1 Structural and optical properties

From the experimental values in Table 2 and Fig. 2, shown the density and molar volume of the barium-borate-rice husk ash glasses system with different BaO content respectively. The replacement of BaO at the expense of all  $\text{B}_2\text{O}_3$  and RHA leads to an increase in density from  $3.1025 \pm 0.0013$  to  $3.6655 \pm 0.1256 \text{ g/cm}^3$ . The molar volume of these glasses system is divided into three regions. In the first region,  $V_m$  increases with increase in BaO content up to 50 wt.% and slowly increase from 50-65 wt.%, which is attributed to the increase in the number of non-bridging oxygens (NBOs). Finally, the third

region BaO=65-70 wt.% the molar volume seen constancy from 36.18-36.26 cm<sup>3</sup>/mol, this may be due to constancy in the number of NBOs. Indicated that BaO in this glass is acting partly as network modifier.

Table 2. Chemical composition, density and molar volume of glass sample

Composition (wt. %)			Density [g/cm <sup>3</sup> ]	V <sub>m</sub> [cm <sup>3</sup> /mol]
BaO (x)	B <sub>2</sub> O <sub>3</sub> (80-x)	RHA		
45	35	20	3.12±0.00	32.12
50	30	20	3.10±0.00	34.00
55	25	20	3.24±0.01	34.26
60	20	20	3.36±0.02	35.00
65	15	20	3.44±0.11	36.18
70	10	20	3.66±0.12	36.26

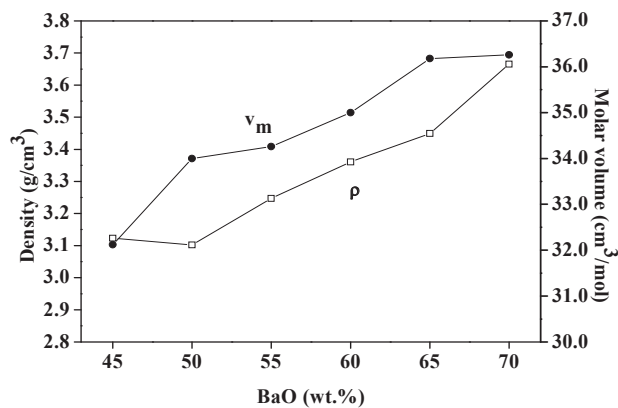


Fig. 2. Density and molar volume as a function of BaO concentration

In order to investigate the optical properties of these glasses at various concentrations, the transmittance was measured as a function of wavelength in the range of 300-700 nm as shown in Fig. 3. All the glasses showed that the transmittance higher than 50% in the visible region.

### 3.2 Radiation shielding properties

For the mass attenuation coefficient from the measured incident and transmitted gamma-ray intensities, it is necessary to know the thickness and density of each sample glasses. Table 3 list the experimental and theoretical values of total mass attenuation coefficients of xBaO:(80-x)B<sub>2</sub>O<sub>3</sub>:20RHA glasses system where 45≤x≤70. From the data seen that, when the BaO concentration increased the mass attenuation increasing too. That means the photon interaction probability increases with higher concentration. In general, the experimental values agree with the theoretical values which are calculated from WinXCom [8], within relative difference 0.03 – 1.42 %.

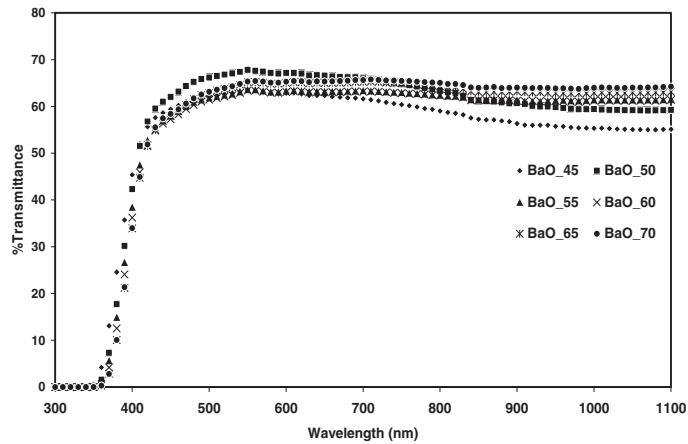
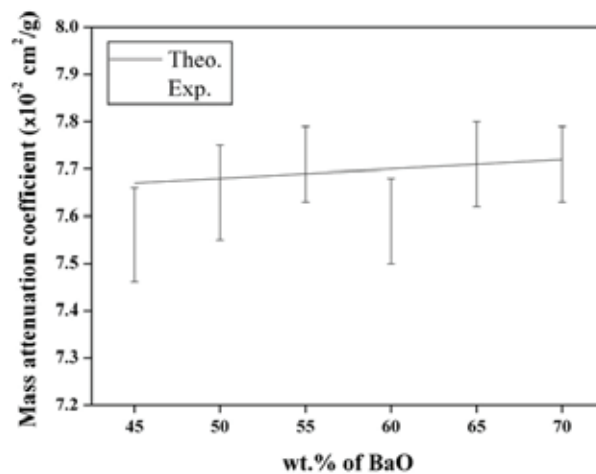


Fig. 3. The spectrum transmittance of the glasses system

Table 3. Experimental and theoretical mass attenuation coefficients of barium-borate-rice husk ash glasses

xBaO:(80-x)B <sub>2</sub> O <sub>3</sub> :20RHA				
Sample No.	wt. % of BaO	Theoretical Value [ $\times 10^{-2}$ cm <sup>2</sup> /g]	Experimental Value [ $\times 10^{-2}$ cm <sup>2</sup> /g]	% RD. <sup>a</sup> of Experimental Value
1	45	7.67	7.56 $\pm$ 0.10	1.40
2	50	7.68	7.65 $\pm$ 0.10	0.42
3	55	7.69	7.71 $\pm$ 0.08	0.29
4	60	7.70	7.59 $\pm$ 0.09	1.42
5	65	7.71	7.71 $\pm$ 0.09	0.03
6	70	7.72	7.70 $\pm$ 0.08	0.25

Fig. 4. Theoretical and experimental mass attenuation coefficients of xBaO:(80-x)B<sub>2</sub>O<sub>3</sub>:20RHA glass system as a function of x (wt.%)

#### 4. Conclusions

Density data and molar volume have been studied on  $x\text{BaO}:(80-x)\text{B}_2\text{O}_3:20\text{RHA}$  glass system to investigated and explore the role of BaO in these glasses. The density and molar volume show an increasing trend. The transmittances of the glasses system are higher than 50% in the visible region. Finally, the mass attenuation of these glasses at photon energy 662 keV increasing too when BaO concentration increases. These data should be helpful in potential applications in gamma-ray shielding.

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